

Stikalni pretvorniki

Seminar: Načrtovanje elektronike za EMC – 29. 3. 2017

Boštjan Glažar

Univerza v Ljubljani

Fakulteta za elektrotehniko

Tržaška cesta 25, SI-1000 Ljubljana

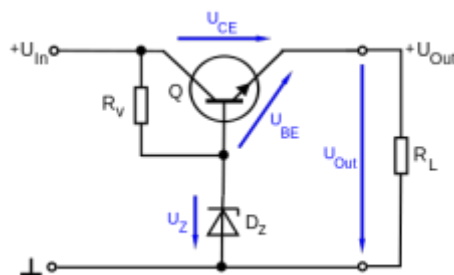


Vsebina

- Prednosti stikalnih pretvornikov
- Neizolirani pretvorniki
- Izolirani pretvorniki
- Krmiljenje
- Parazitne lastnosti transformatorja / sklopljene induktivnosti
- Pomožna vezja
- PFC

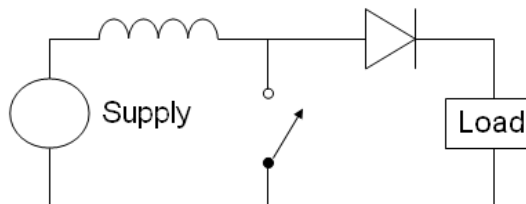
Zakaj stikalni pretvornik

- Izkoristek



$$\eta < \frac{U_{out}}{U_{in}}$$

- $U_{out} > U_{in}$

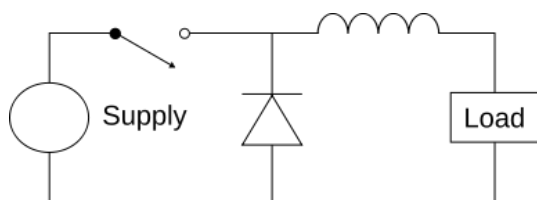


- Velikost

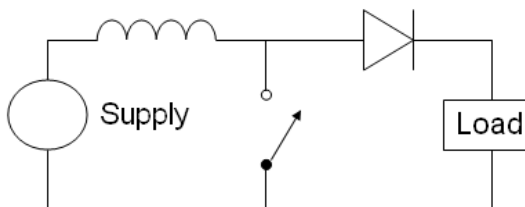


Neizolirani pretvorniki I

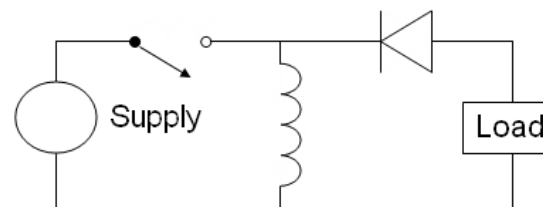
- Navzdol
(step-down, buck)



- Navzgor
(step-up, boost)



- Navzdol/Navzgor
(buck-boost)



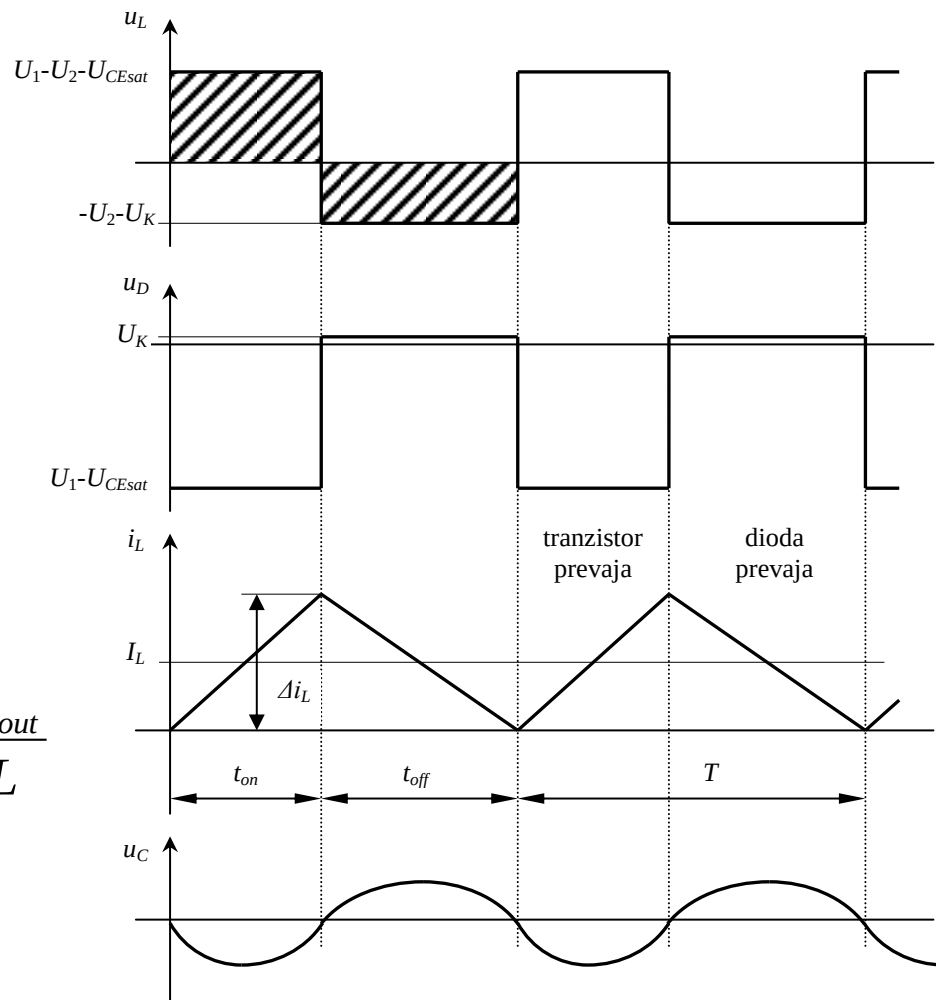
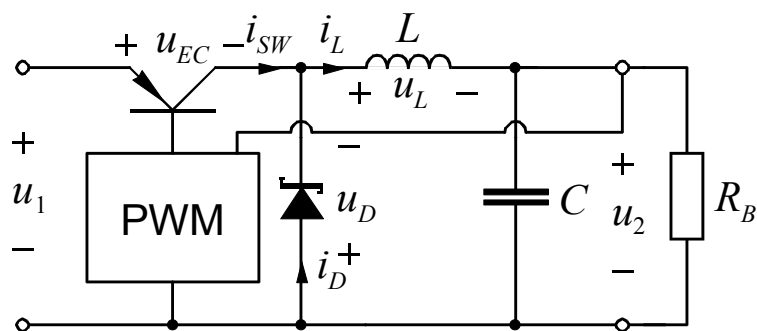
- Osnovne enačbe za neprekinjeno delovanje:

$$U_{out} = D \cdot U_{in}$$

$$U_{out} = \frac{1}{1-D} \cdot U_{in}$$

$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

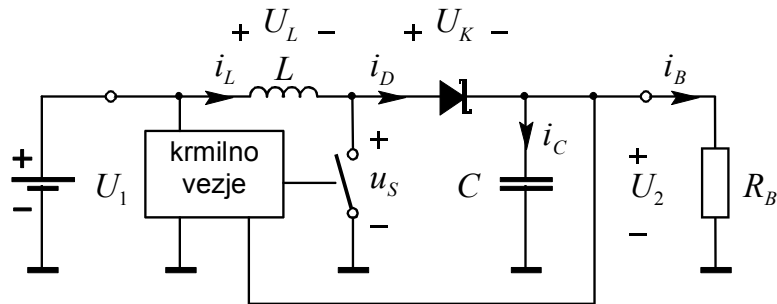
Pretvornik navzdol (step-down, buck)



$$U_{out} = D \cdot U_{in}$$

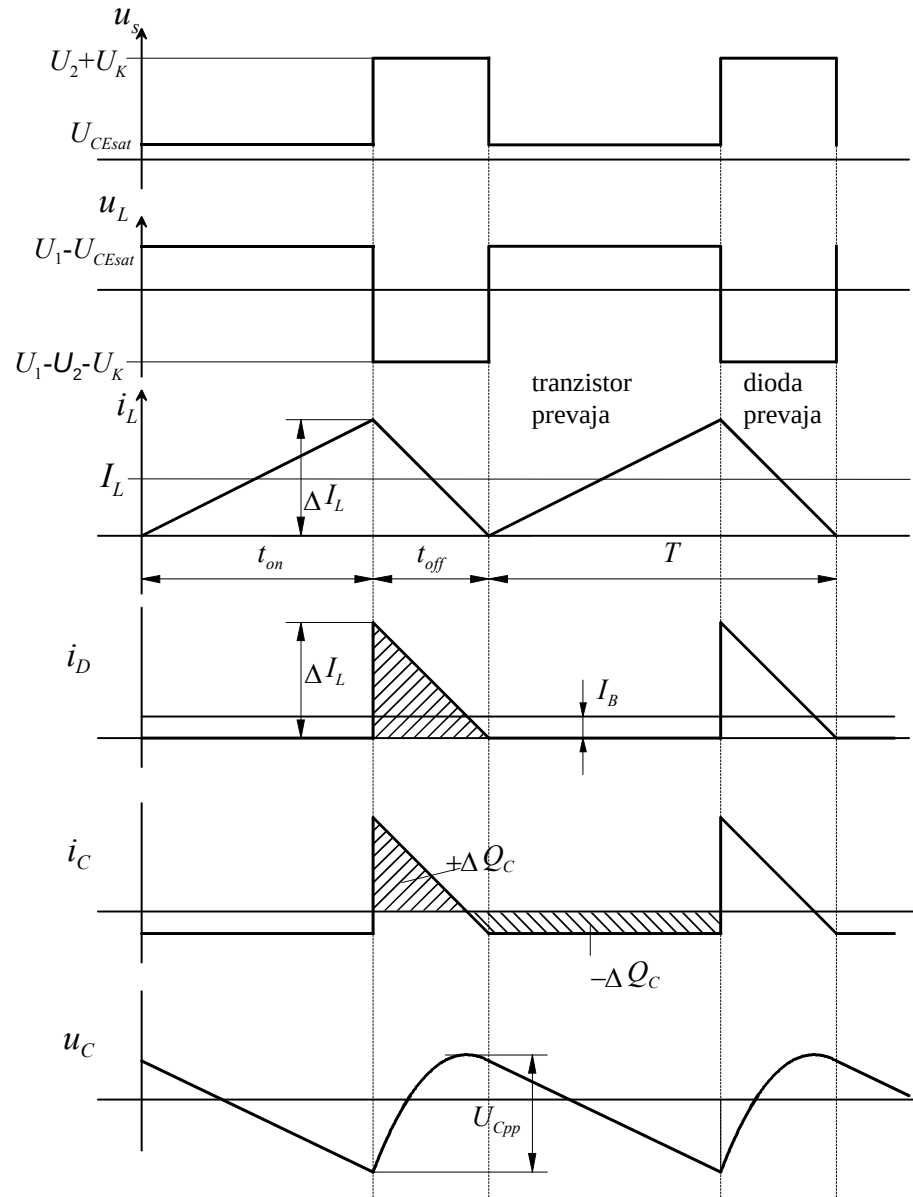
$$\Delta I_L = D \cdot T \cdot \frac{U_{in} - U_{out}}{L} = (1 - D) \cdot T \cdot \frac{U_{out}}{L}$$

Pretvornik navzgor (step-up, boost)

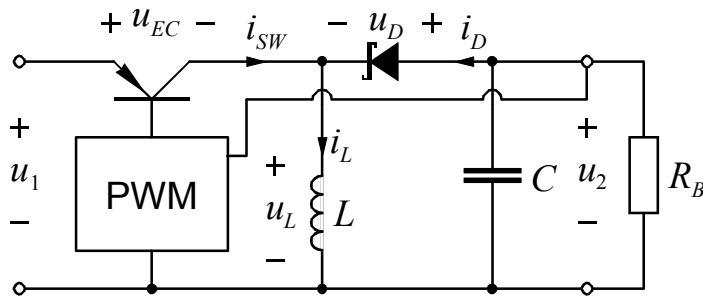


$$U_{out} = \frac{1}{1-D} \cdot U_{in}$$

$$\Delta I_L = D \cdot T \cdot \frac{U_{in}}{L} = (1-D) \cdot T \cdot \frac{U_{out} - U_{in}}{L}$$

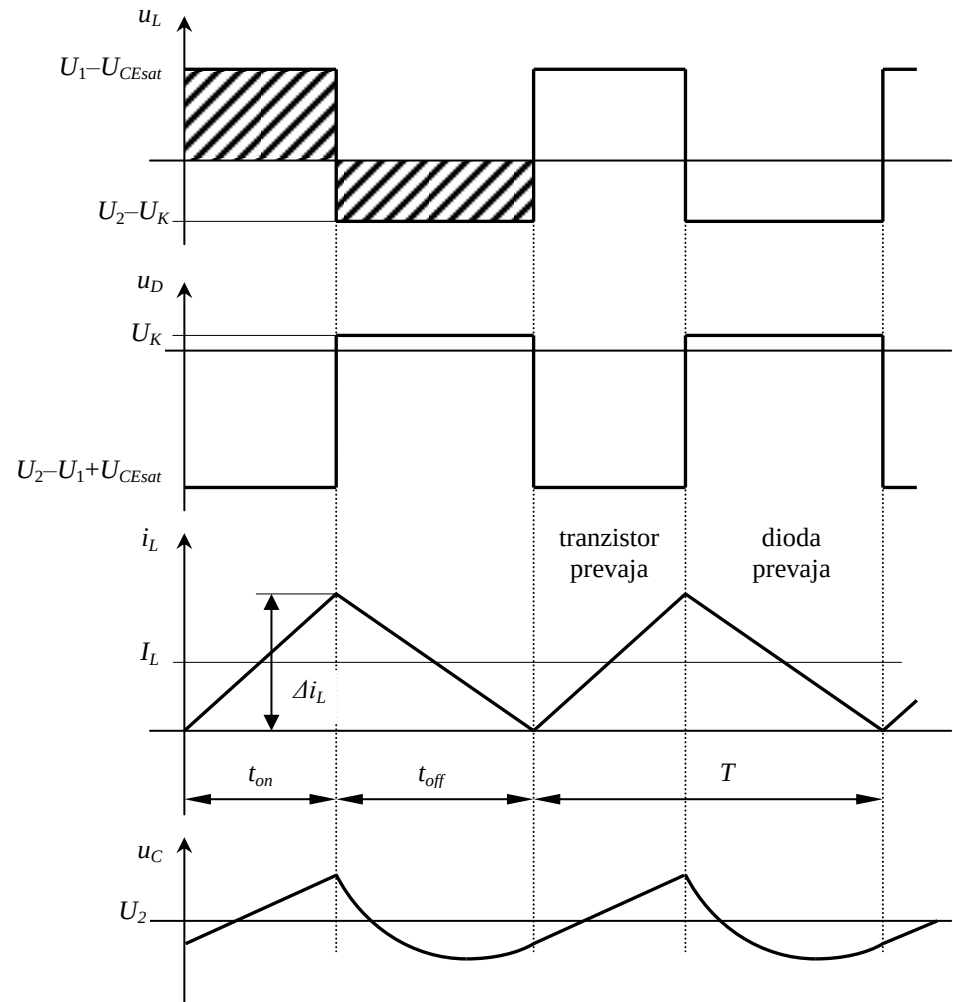


Pretvornik navzdol/navzgor invertirajoči (buck/boost, inverting, non-isolated flyback)

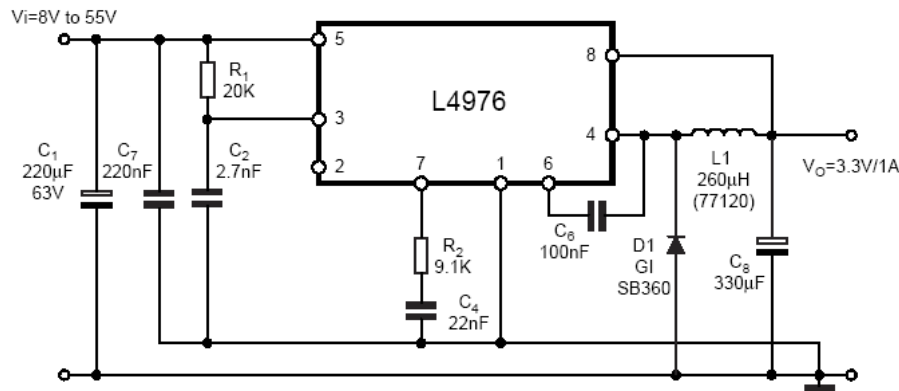


$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

$$\Delta I_L = D \cdot T \cdot \frac{U_{in}}{L} = (1-D) \cdot T \cdot \frac{U_{out}}{L}$$

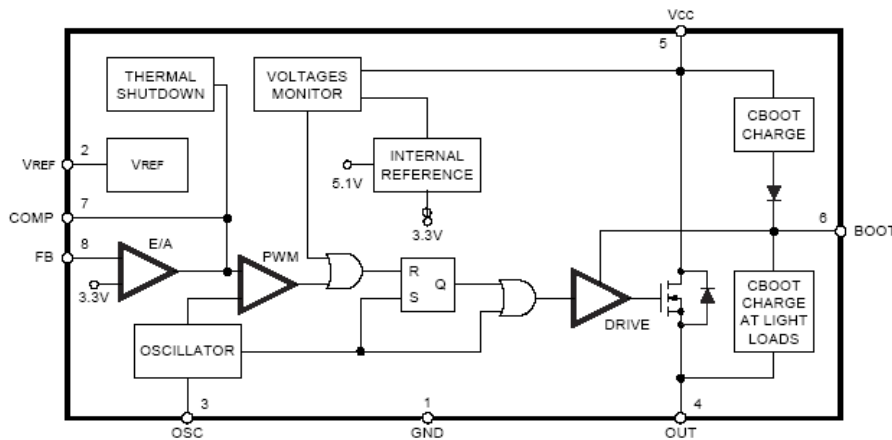


Primer izvedbe – pretvornik navzdol

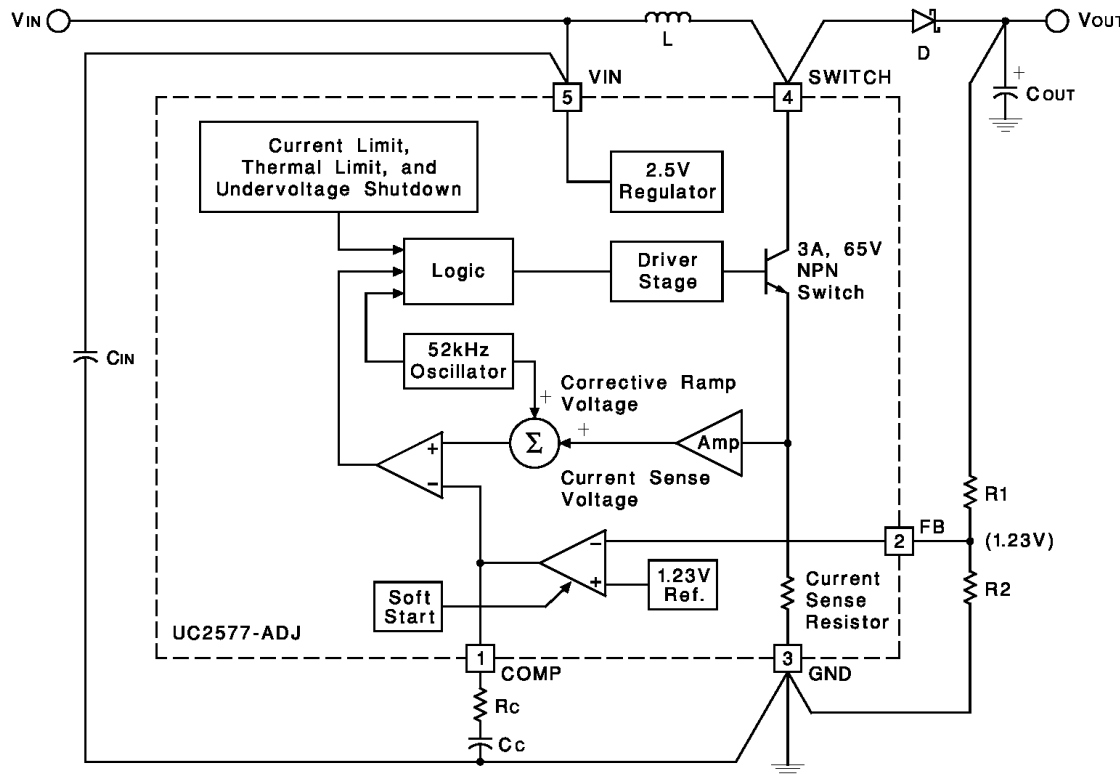


■ ST L4976

- › Vhod: 8 – 55 V
- › Izhod: do 1 A
- › Frekvenca do 300 kHz
- › DIP8, SO16
- › Izkoristek: 85 % @ 24/3,3 V



Primer izvedbe – pretvornik navzgor



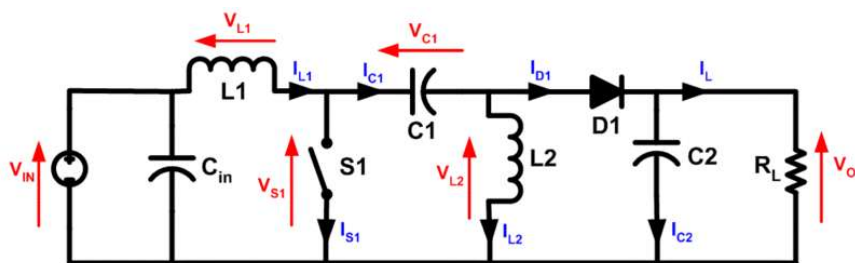
■ Texas Instruments (Unitrode) UC2577

- › Topologije: navzgor, flyback, forward
- › Vhod: do 40 V
- › Stikalo: 3 A, 65 V
- › To-220-5
- › Izkoristek: 80 % @ 5 / 12 V, 800 mA

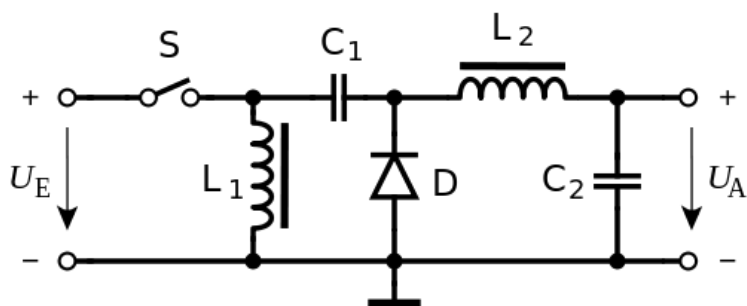
Neizolirani pretvorniki II

▪ SEPIC

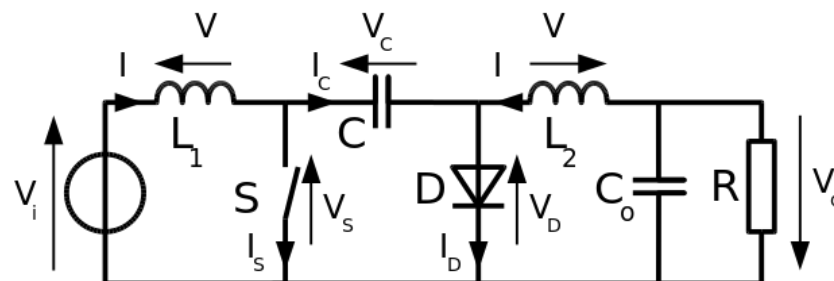
(Single-ended primary-inductor converter)



▪ Zeta



▪ Čuk



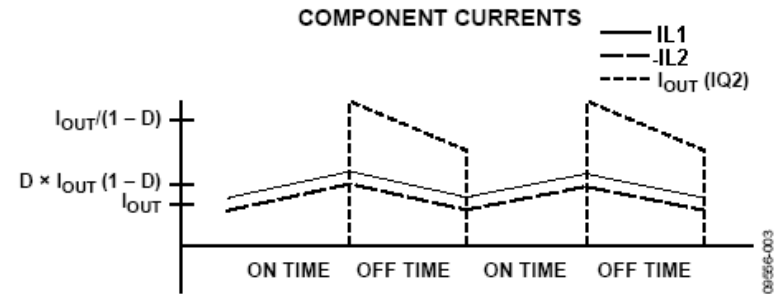
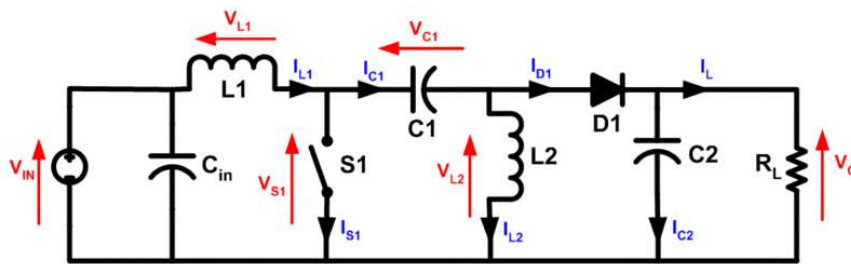
▪ Neprekinjeno delovanje:

$$U_{out} = -\frac{D}{1-D} \cdot U_{in}$$

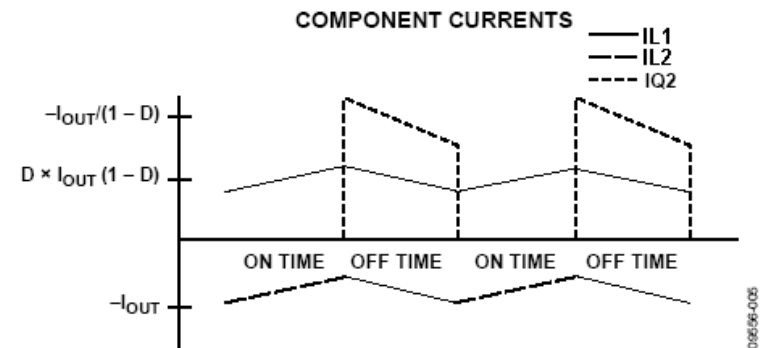
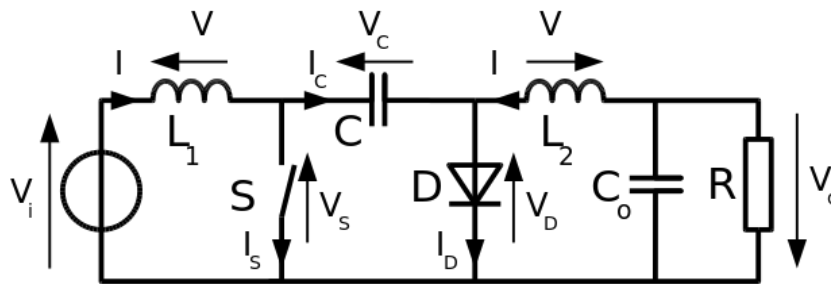
$$U_{out} = \frac{D}{1-D} \cdot U_{in}$$

Neizolirani pretvorniki II

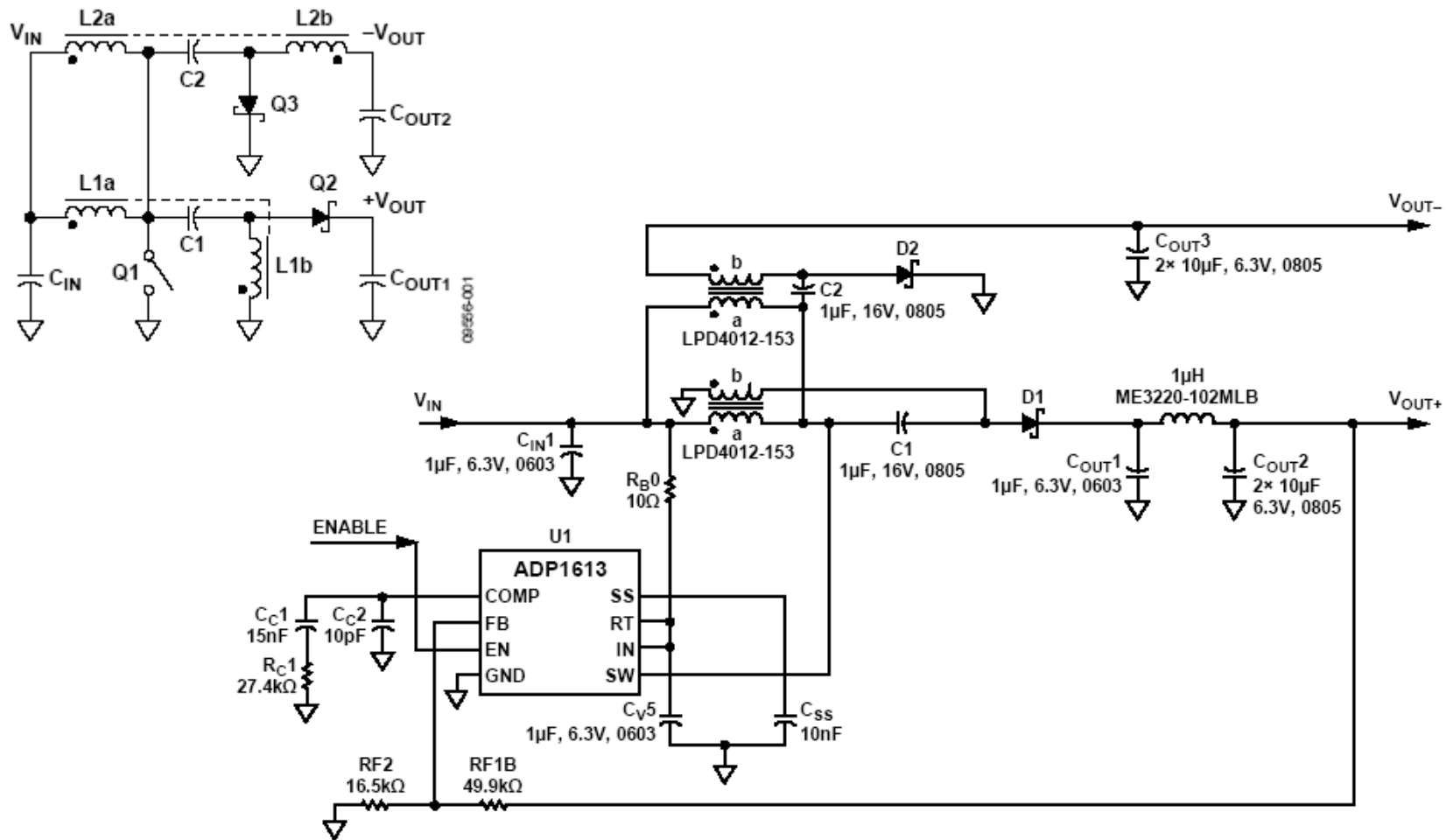
SEPIC



Ćuk



Primer izvedbe – Dvojni pretvornik

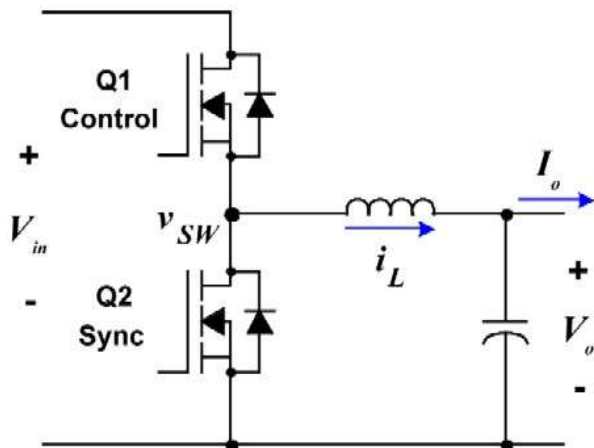


Vir: Application note Analog Devices AN-1106

Izboljšave

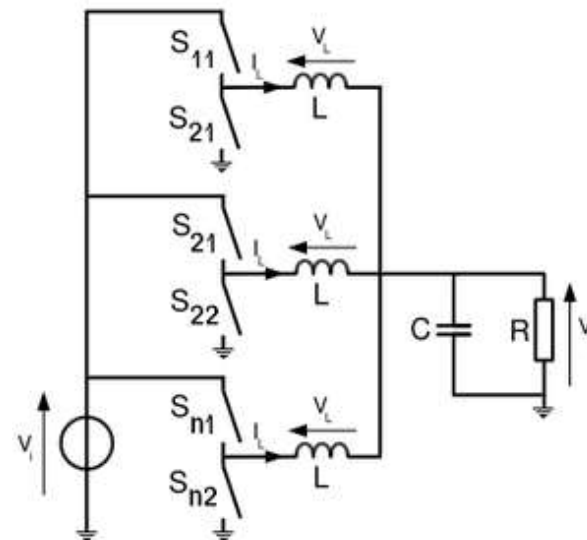
▪ Sinhroni pretvornik

- › Tranzistor namesto diode



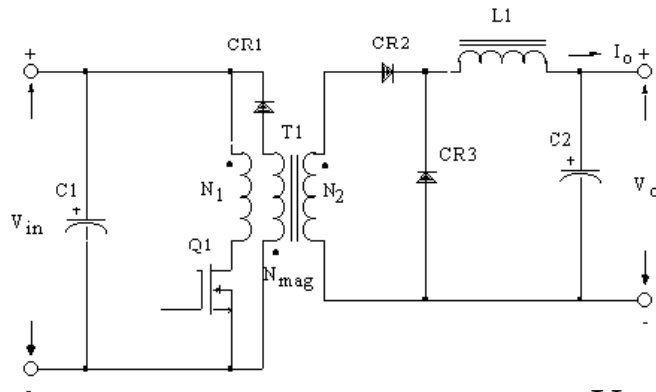
▪ Večfazni pretvornik

- › Velik izhodni tok
- › Hitrejši odziv
- › Manjša valovitost toka

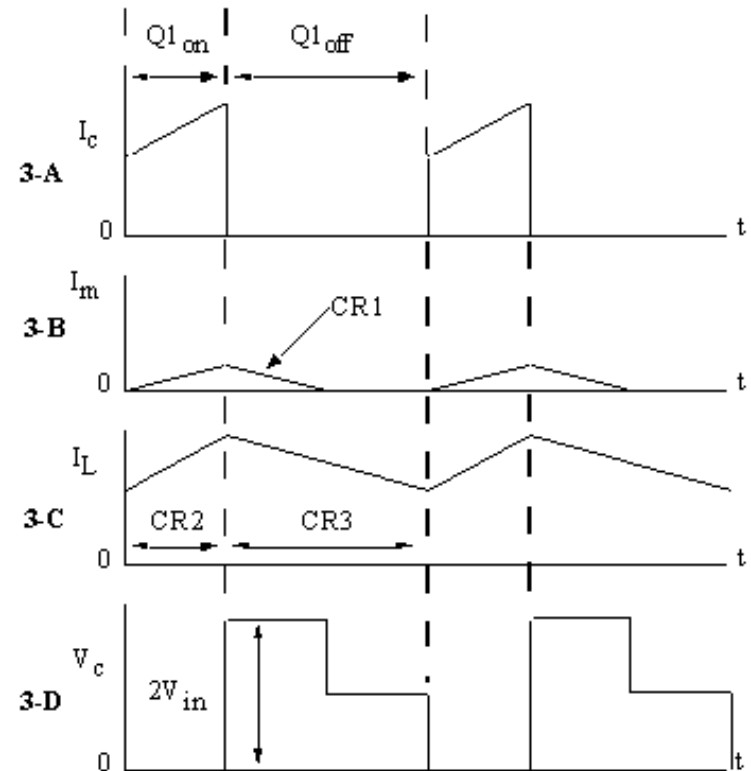
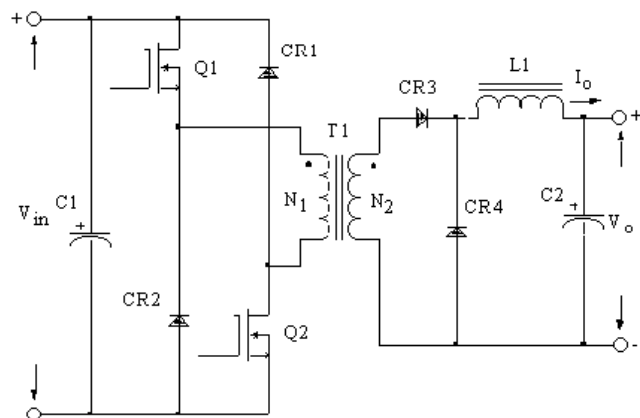


Vir slik: Eric Persson, How FET selection can optimize synchronous buck converter efficiency, EEtimes;

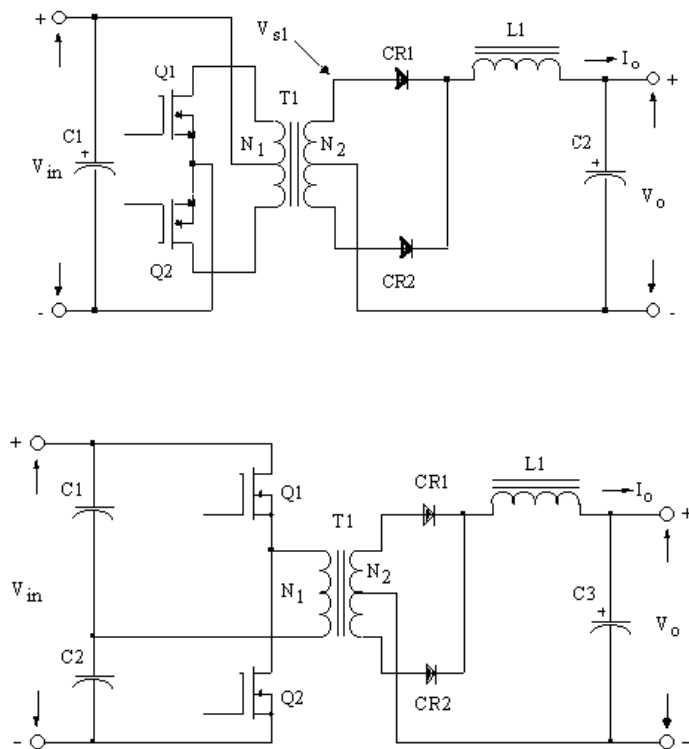
Izolirani p. l - Forward (magnetenje v eni smeri)



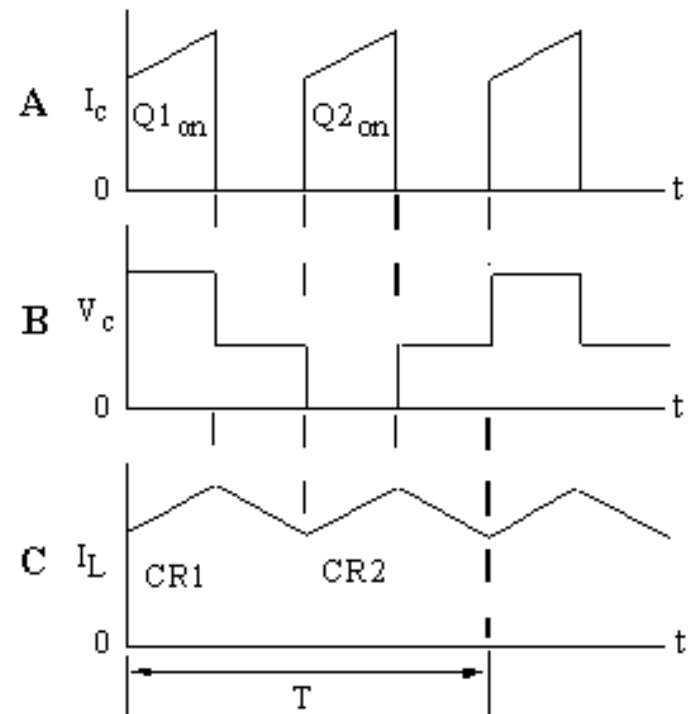
$$U_{out} = D \cdot \frac{N_2}{N_1} \cdot U_{in}$$



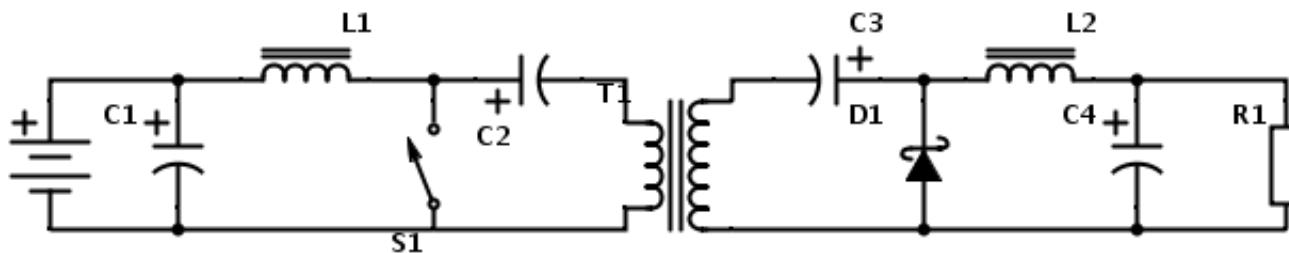
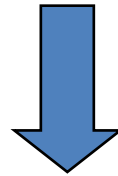
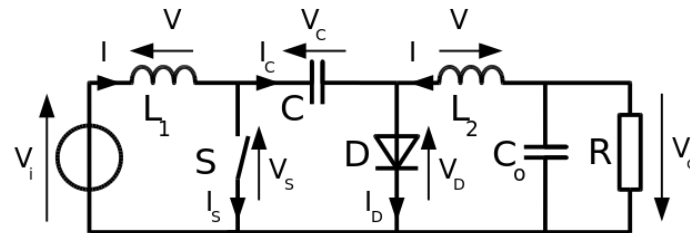
Izolirani p. II - Forward (magnetenje v obe smeri)



$$U_{out} = D \cdot \frac{N_2}{N_1} \cdot U_{in}$$

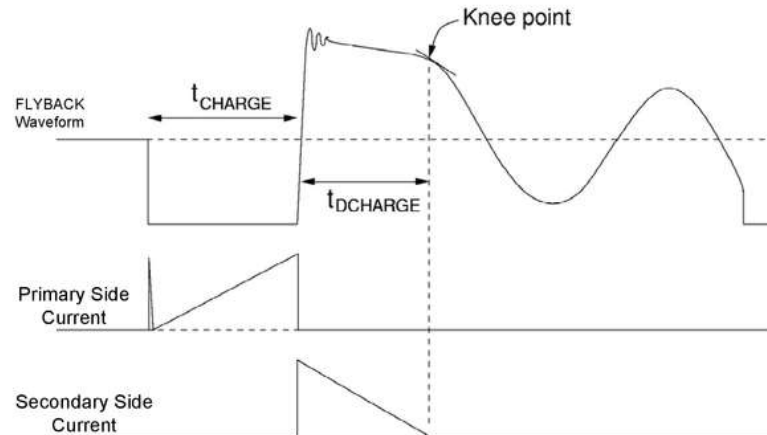
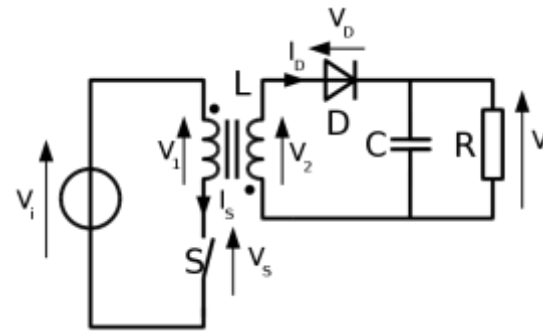
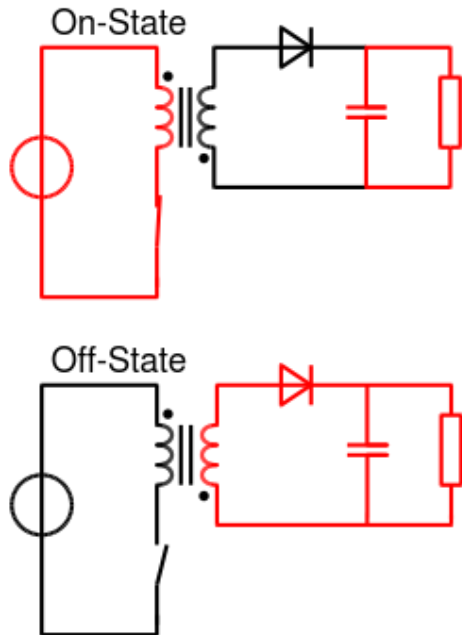


Izolirani p. III – Čuk pretvornik

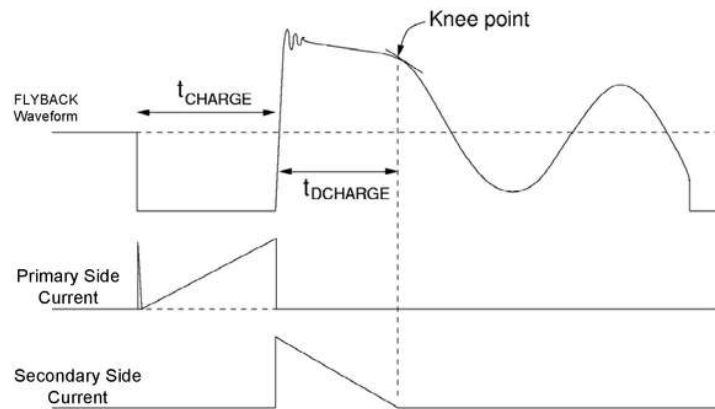


Izolirani pretvorniki IV

Flyback



Flyback



■ Neprekinjeno delovanje

$$U_{out} = \frac{N_2}{N_1} \cdot \frac{D}{1-D} \cdot U_{in}$$

■ Prekinjeno delovanje

$$I_{primP} = \frac{U_{in} \cdot t_{on}}{L_{prim}}$$

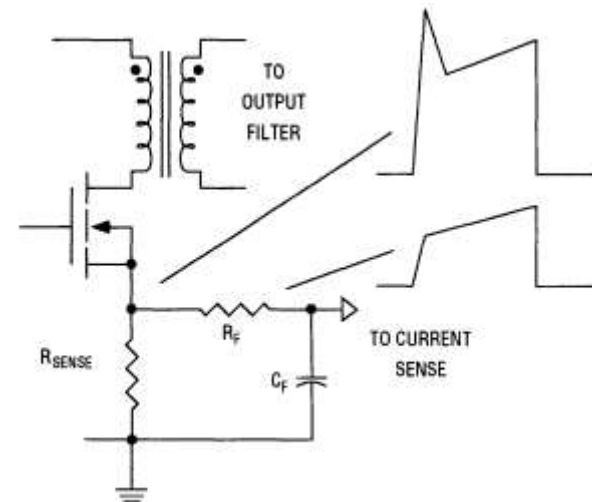
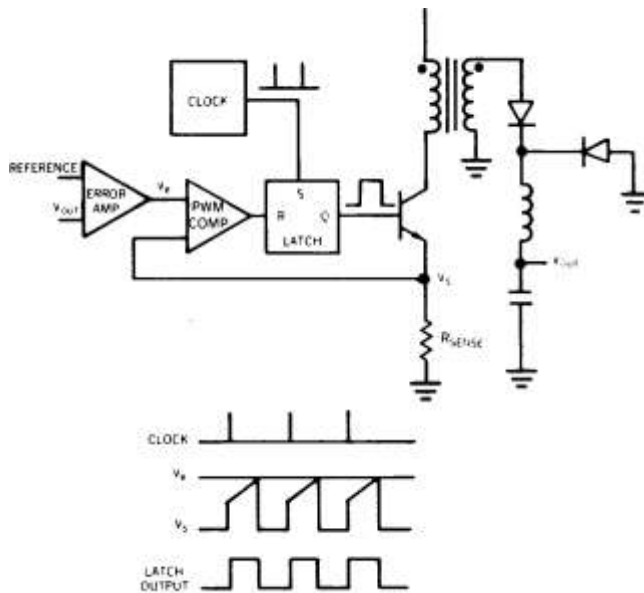
$$P_{DCM} = \frac{I_{primP}^2 \cdot L_{prim}}{2} \cdot f$$

$$U_{out} = D \cdot \sqrt{\frac{R_L \cdot T}{2 \cdot L_{prim}}} \cdot U_{in}$$

Krmiljenje I

- Napetostno (voltage-mode)
 - › Signal napake – žaga > PWM
- Tokovno (current-mode)

- Filtriranje špic
 - › RC filter
 - › Mrtvi čas

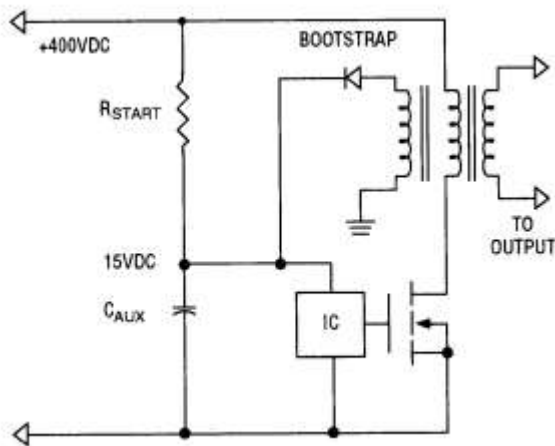


Vir slik: Unitrode U-93, U-128 app.note

Krmiljenje II

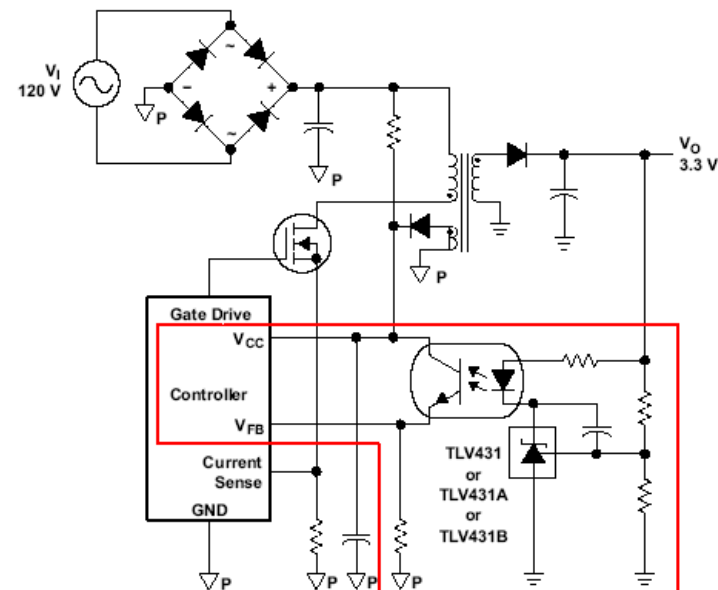
▪ Napajanje krmilnika

- › Dodatni napajalnik
- › Upor / dodatno navitje



▪ Povratna vezava

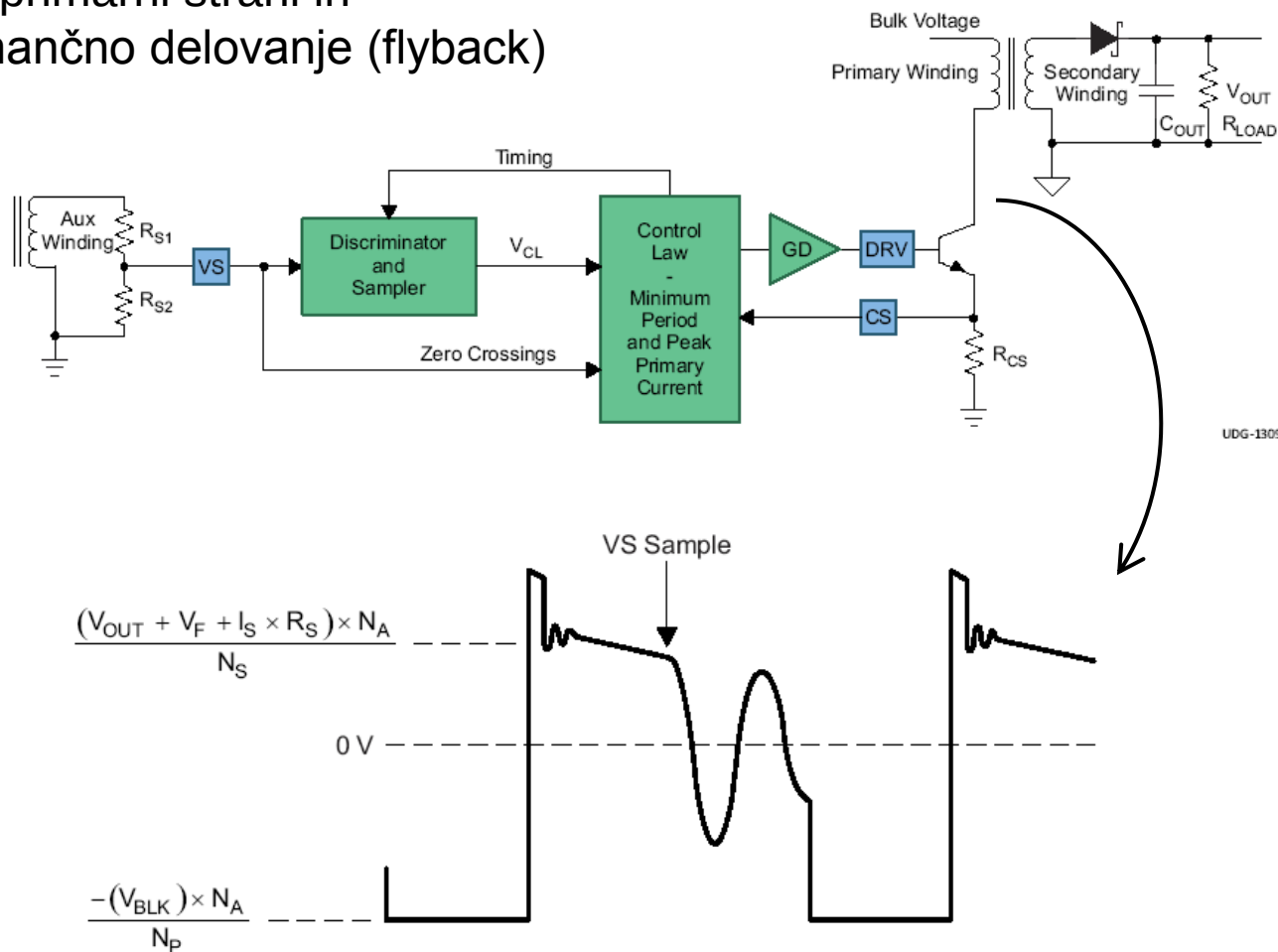
- › Optično spojnik
- › Transformator
- › Meritev na primarni strani



Vir slik: Texas Instruments TLV431 datasheet, U-128 app.note

Krmiljenje III

Meritev na primarni strani in
kvazi-resonančno delovanje (flyback)

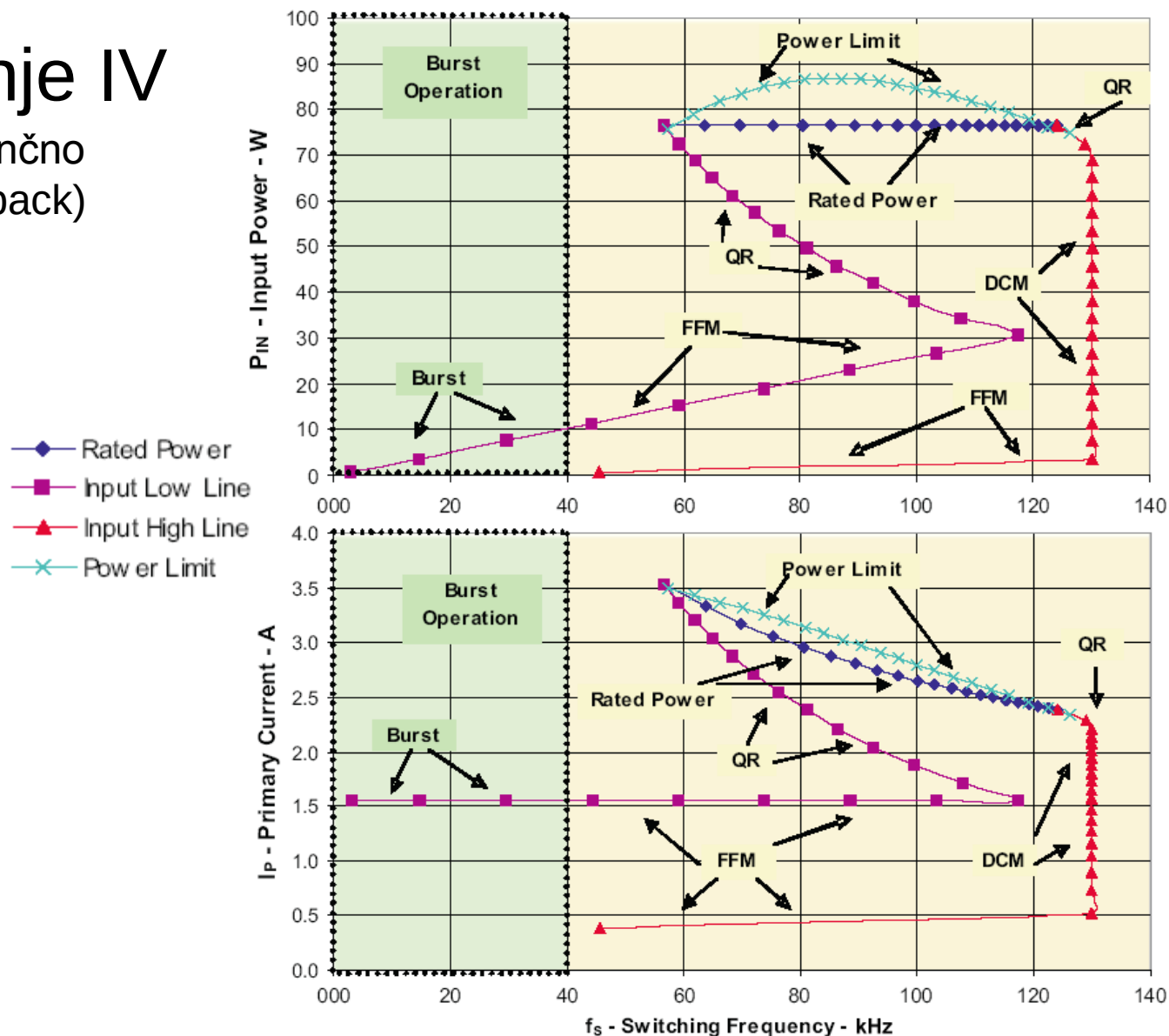


UDG-13093

Vir slik: UCC28720 (SLUSBE8B)

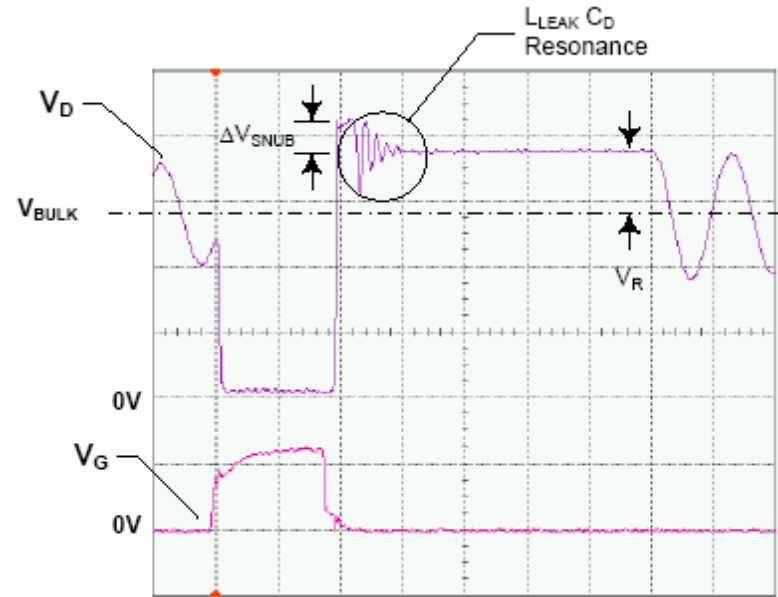
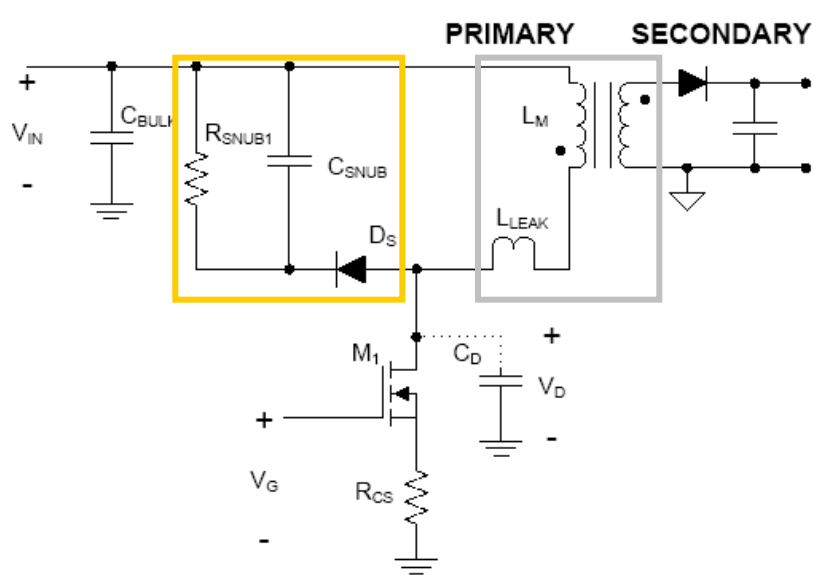
Krmiljenje IV

Kvazi-resonančno
delovanje(flyback)



Vir slik: Design Considerations for the UCC28600 (SLUA399B)

Sklopljena tuljava – stresana induktivnost



Vir slik: UCC28600 (SLUS646K)

Sklopljena tuljava – medovojna kapacitivnost

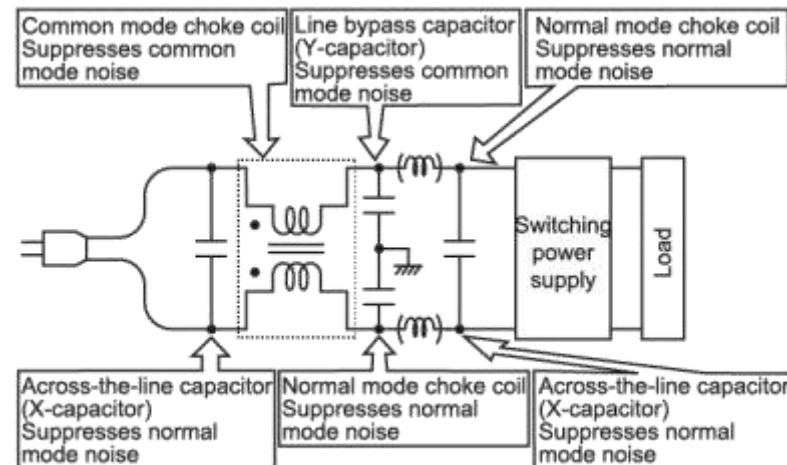
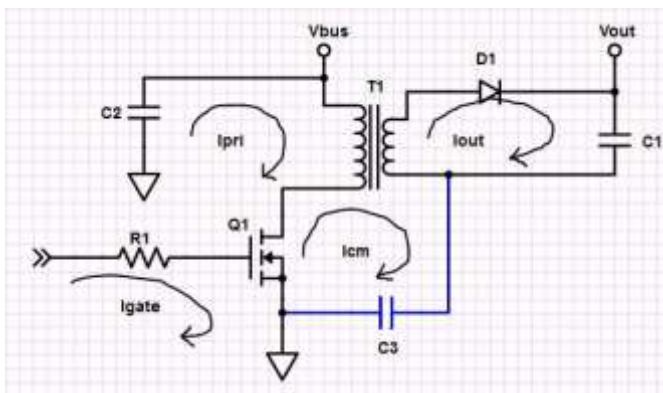
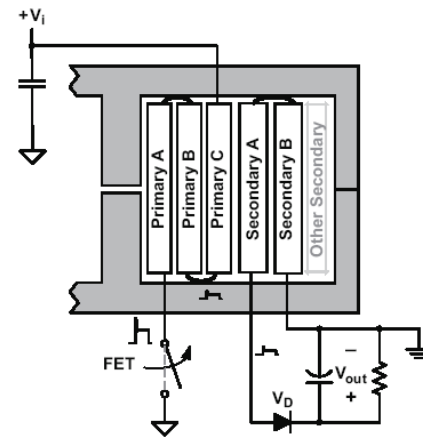
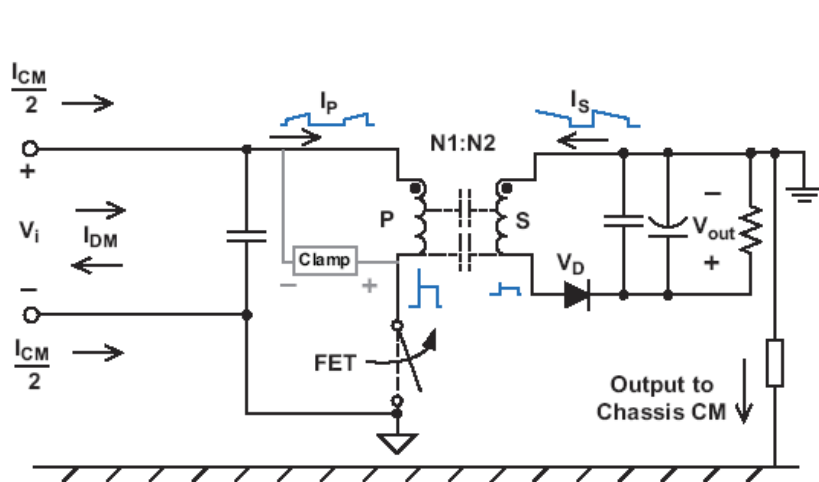
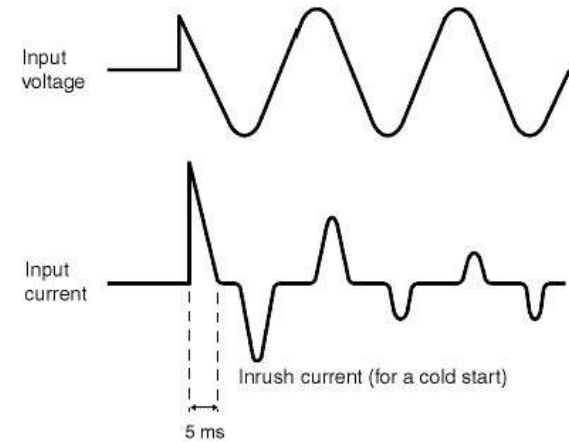
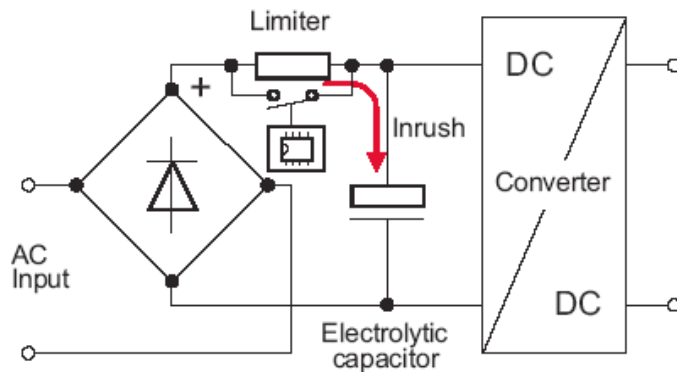
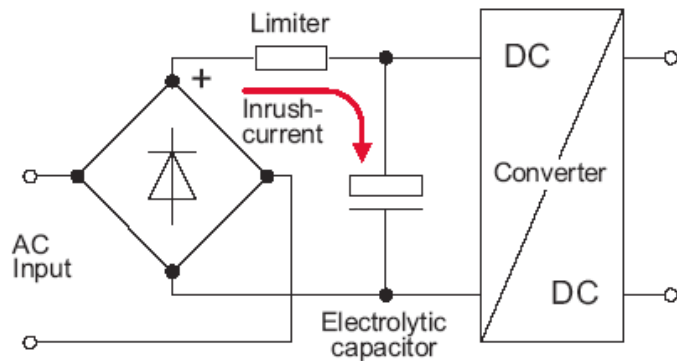


Fig. 3. Example of a filter configuration for a commercial power supply line

Vir slik: Under the Hood of Flyback SMPS Designs, Texas Instruments; Justin Clack, Minimizing EMI Problems in Noisy Switching Converter Circuits ...and Bears, EEWiki; Murata

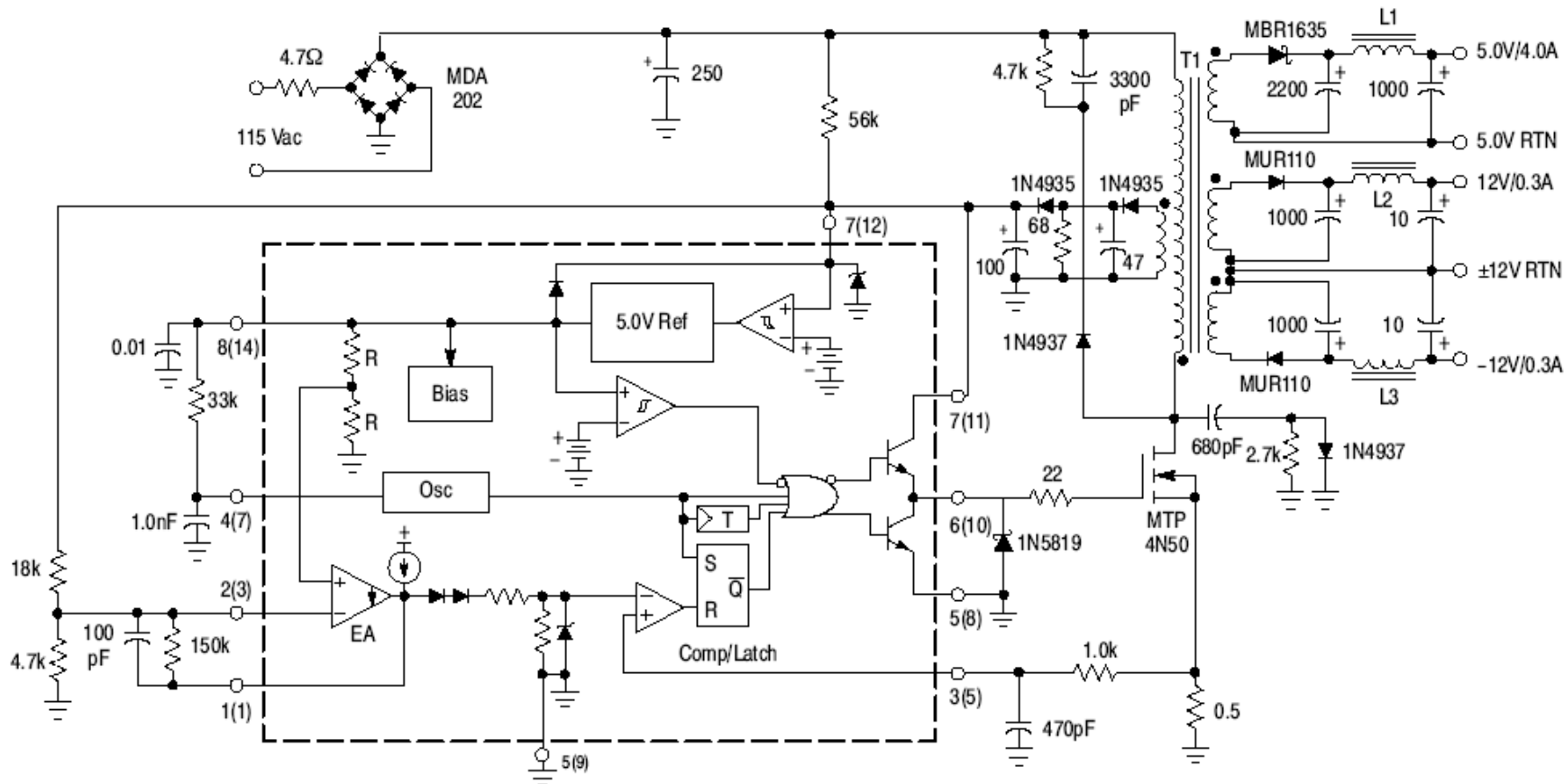
Vklopni tok (Inrush current)



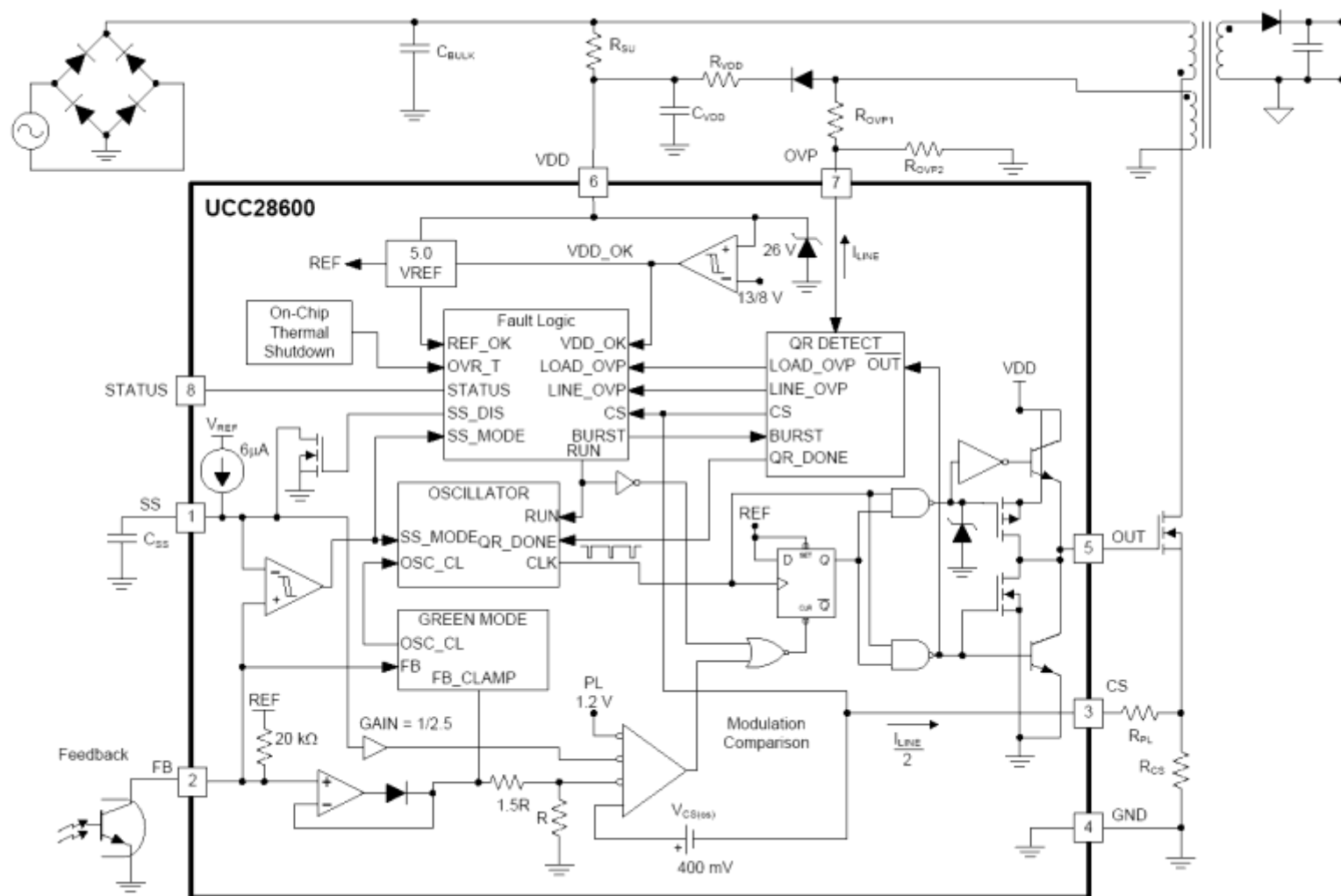
- Omejevanje:
 - > Upor (izgube?)
 - > NTC (topli vklop?)
 - > upor + stikalo

Vir slik: graf: Omron FAQ01874, shema: Pulspower

ON Semiconductor UC3844/45



Primer izvedbe – flyback



Literatura

- Power Semiconductor Applications – Chapter 2: Switched Mode Power Supplies, Philips Semiconductors, http://www.moodle2.tfe.umu.se/pluginfile.php/60819/mod_label/intro/nxp/APPCHP2.pdf
- Under the Hood of Flyback SMPS Designs – SLUP261, Texas Instruments, <http://www.ti.com/lit/ml/slup261/slup261.pdf>
- Design Considerations for the UCC28600 – SLUA299B, Texas Instruments (Lisa Dinwoodie)
- Compensation Design With TL431 for UCC28600 – SLUA671, Texas Instruments (Max Han, Zhong Ye)

Pozor, visoka napetost! – Smrtno nevarno

- (Skoraj) vsi primarni deli omrežnega napajalnika, **vklučno z maso**, so na smrtno nevarni napetosti!
- Brez dodatnih ukrepov ne smemo priključiti mase osciloskopa na primarno maso!
- Ob morebitnem testiranju napajalnika je priporočljiva uporaba ločilnega transformatorja. Kljub transformatorju je potrebna pazljivost, saj napajalna napetost ostaja enaka!
- Če ločilni transformator ni na voljo, je priporočljivo vsaj FID stikalo.
- Vhodni elektrolitski kondenzator lahko ostane napolnjen tudi več minut po izklopu napajalnika iz omrežja.

Hvala za vašu pozornost